GLACIATION ON THE NORTH SIDE OF THE WRANGELL MOUNTAINS, ALASKA[1]

STEPHEN R. CAPPS

Since the pioneer trip of Lieutenant Henry T. Allen, in 1885, it has been known that a range of mountains lying north of the Chisana River, and later called Wrangell Mountains,[2] was heavily glaciated. The glacial phenomena of the Copper River basin and the south side of this range have been more or less fully discussed by various writers,[3] and some notes have been published[4] on the occurrence and position of glaciers and of Pleistocene deposits on the north side of this range, and in the White River Valley. During the summer of 1908, it was the writer's privilege to take a trip into the region north of the Wrangell Mountains with a party from the U. S. Geological Survey, in charge of Mr. Fred H. Moffit. The attempt is here made to summarize the glacial conditions of this region. In certain portions not personally visited, the unpublished maps and notes of F. C. Schrader, collected in 1902, have been drawn upon. The names of rivers, mountains, etc., referred to are taken from the topographic maps of the U. S. Geological Survey.[5]

The dominant topographic feature of the region under discussion is the Wrangell Mountains, extending from the Copper River basin in a southeastern direction to Russell Glacier and the headwaters of

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] F. C. Schrader, *20th Ann. Rept.*, U. S. Geological Survey, Part VII, pp. 377, 378.

[3] F. C. Schrader and A. C. Spencer, *Geology and Mining Industry of a Portion of the Copper River District*, Alaska, 1901, p. 30; C. W. Hayes, *Nat. Geog. Mag.*, Vol. IV, 1892; Oscar Rohn, *21st Ann. Rept.*, U. S. Geological Survey, Part II, pp. 399–439; W. C. Mendenhall, "Geology of Central Copper River Region, Alaska," U. S. Geological Survey, *P. P. 41*, 1905.

[4] C. W. Hayes, *op. cit.*; A. H. Brooks, *A Reconnaissance from Pyramid Harbor to Eagle City, etc.*, U. S. Geological Survey, 1901.

[5] *Central Copper River Region, Alaska*, U. S. Geological Survey, 1902; *Headwater Regions of Copper, Nabesna, and Chisana Rivers, Alaska*, U. S. Geological Survey, 1902.

the Nizina River. In this range two peaks, Mount Sanford and Mount Blackburn, rise to heights of more than 16,000 feet. Mount Wrangell, a broad, dome-shaped mass, is 14,000 feet high, and many peaks of the range have elevations of from 12,000 to 13,000 feet. East of the Wrangell Mountains, and separated from them by Skolai Pass, is the northwest end of the St. Elias Range. The highest peak seen was Mount Natazhat, near the international boundary. This prominent mountain has a height of about 13,000 feet. North of the Wrangell Mountains and parallel with them, are the Nutzotin Mountains. The two ranges are separated on the west by the Copper River basin, and on the east by an area of low hills, but between the heads of the Copper and Chisana rivers, the two ranges approach one another without any sharp topographic break. The Nutzotin Mountains reach elevations, in their higher portions, of 8,000 to 10,000 feet. The large rivers are the Copper, which makes a great curve and flows south into the Gulf of Alaska, and the Nabesna, Chisana, and White rivers, all of which join the Yukon drainage.

Pleistocene Geology

The region covered by this report is bordered on the south by the high ranges of the Wrangell and St. Elias mountains. The name "Skolai Mountains" had been applied to a portion of this range, on either side of Skolai Pass. Structurally and physiographically, however, the Wrangell Mountains are continuous with the Skolai Mountains, which in turn are directly continuous with the St. Elias Range to the southeast. As the term Skolai Mountains does not apply to any natural division of this range, it is here omitted.

CENTERS OF GLACIATION

WRANGELL MOUNTAINS

A very important feature of the Wrangell Mountains is the great ice-cap which occupies the crest of the range, and which has its greatest development in the region around Mount Wrangell (Fig. 1). From the periphery of this great feeding-ground valley glaciers extend in all directions down the more important drainage lines. This report is concerned only with those glaciers of this group which extend to the north and northeast. In the Wrangell Mountains,

beyond the edge of the great ice-cap, there are numerous localities where the elevation is sufficient to start small glaciers. Small ice-tongues of this type occur between the Copper and Nabesna glaciers, and in the mountains east of the upper Nabesna River.

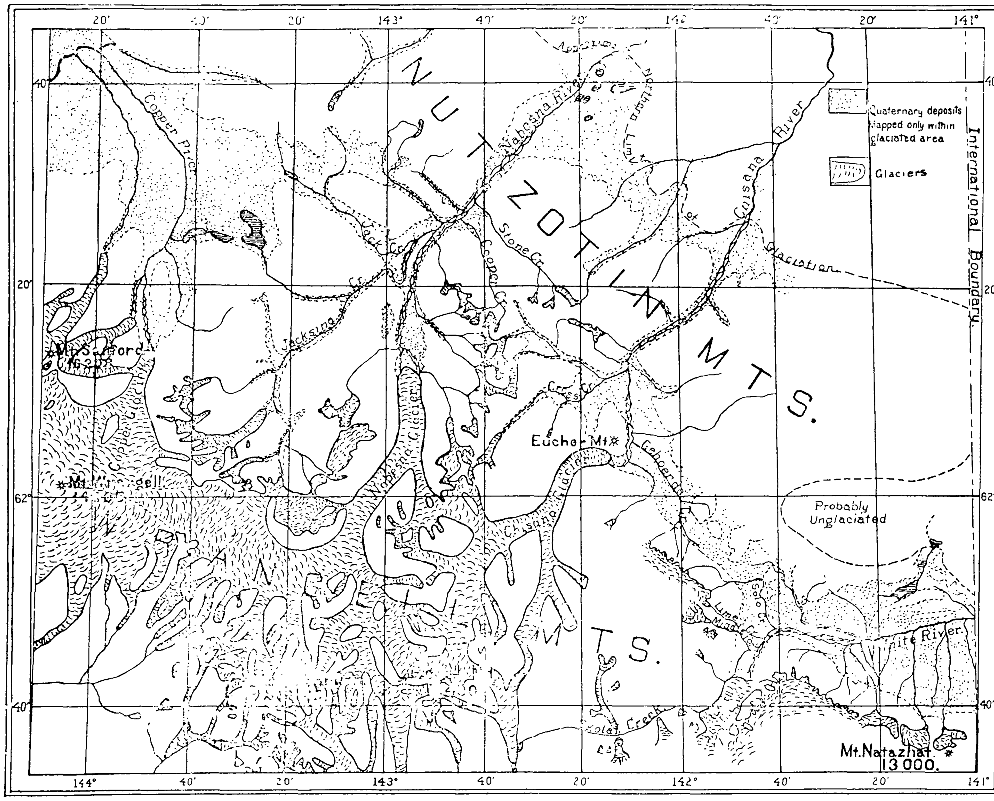

FIG. 1.—Map of a part of the Wrangell and Nutzotin mountains, Alaska. The existing glaciers are shown by the broken lines; the dotted areas show the distribution of the Quaternary deposits. The line of dashes indicates approximately the northern limit to which earlier glaciers reached. Compiled from published and unpublished maps of the U. S. Geological Survey.

ST. ELIAS MOUNTAINS

Second in importance in the region here discussed to the Mount Wrangell distributing center, is the ice-cap which occupies the St. Elias Mountains, south of the White River. Little is known of this ice-field, except along its northern border. As far as can be

seen from the White River Valley, all of the main range which lies west of the international boundary and south of the White River is capped with ice above an elevation of about 7,500 feet. As in the Wrangell Mountains, all of the important valleys which head back into the range are occupied by valley glaciers.

NUTZOTIN MOUNTAINS

A few small glaciers have survived in the more favorably situated valleys of the Nutzotin Mountains between the Chisana River and Suslota Pass. The largest of these is not more than three miles long.

INFLUENCE OF PRESENT GLACIERS UPON THEIR VALLEYS

Erosive effects.—The existing glaciers are now exerting a most important influence upon the shapes of their valleys. By the rasping of their beds with rock fragments held in the moving ice; by freezing to the bed rock and plucking out blocks of it; and by undermining the valley walls and causing the material above to fall down upon the glacier, the ice is enabled to remove great quantities of material from the valleys in which it is confined. The result of this erosion is to be seen in the characteristic shapes of the valleys in which it has been effective. Instead of the usual V shape of stream-cut valleys in rugged, youthful mountains, we find everywhere a broad U-shaped cross-section. The ice tends also to steepen the valley gradient toward the glacier-head, but to reduce it toward the foot of the glacier. In areas from which the ice has retreated, the bedrock often shows well-marked striations, or surfaces which have been smoothed or polished by the grinding. There is also a notable absence of sharp angular surfaces or protrusions of the bedrock, as all such projections have been worn away by the ice.

Effects on valleys below glaciers.—Glaciers also have an important influence upon the topography of the valleys below the ice-edge. All of the material which a glacier carries, either inclosed in the ice, or upon its surface, is ultimately carried toward the terminus and dropped as the ice melts away. It often accumulates as considerable moraine deposits, consisting of a heterogeneous mixture of angular or partly rounded rock fragments with finer clays. Often striae can be found upon the included bowlders.

Since the ice-borne materials are either deposited at the melting edge of a glacier, or beneath the body of the melting portion of the ice, there is always a great deal of running water present. Often streams of large volume flow out from beneath the glacier, but the volume of flow varies seasonably and daily as the temperature rises and falls. At times of rapid melting the streams carry large volumes of water, and are able to handle a great amount of the débris brought down by the ice. The material may be carried for long distances, or much of it may be dropped within a short distance from the glacier. The daily fluctuations in volume of the streams is an important factor in both the transportation and deposition of the débris.

Materials which have been deposited by streams differ notably in structure from those deposited directly by the ice. The water tends to assort the materials, and while the stratification may be very imperfect, the structure is readily distinguishable from that of glacial till.

Both the moraines and the stream-laid gravels form important topographic features in the valleys below the glaciers. The moraines are usually most prominent near the ice-edge, as they are readily cut away and destroyed by the streams. The outwash gravels are often of great extent, and the broad gravel bars with their anastamosing streams cover the valley floors of almost all the glacier-fed drainage lines.

EVIDENCES OF EARLIER AND MORE EXTENSIVE GLACIERS

We have seen that glaciers have an important influence upon the valleys which they occupy, both in determining the shape of the valleys, and in causing the deposition of moraines and gravels. These evidences are definite, and would remain even if the ice should melt and disappear. In the region under discussion there is abundant evidence of this sort, which shows that at no distant geological period the glaciers were of much greater size and extent than they are now. The valleys have been broadened and deepened, and show a marked U shape in cross-section far below the limits of the present ice. Furthermore, the rock surfaces are often striated, and there are unmistakable deposits of glacial till at many points from which the ice has long ago disappeared. In the Nabesna Valley, for example, the ice probably extended 40 or 50 miles to the northeast from the edge

of the present glacier, and spread out upon the plain at the north base of the Nutzotin Mountains. At this time, the glacier was about 100 miles long from its terminus to the top of Mount Wrangell, where it headed. Other glaciers of this region were proportionately greater.

An attempt has been made, based on somewhat incomplete data, to show the northern limits of the glaciers in this region at the time of their maximum extent (Fig. 1). The glaciated area includes all of the Wrangell, Nutzotin, and Skolai mountains. It is probable that at no time were the Nutzotin Mountains entirely ice-covered, but only the highest peaks and ridges projected above the glacier, and the total area of these projecting points was very small.

COPPER RIVER VALLEY

The Copper River heads in a glacier which receives the ice from the north slope of Mount Wrangell and from a part of the east slope of Mount Sanford. Although seen only at a distance by the writer, its general characteristics can be learned from the topographic map. In length this glacier is much inferior to those in the valleys of the Nabesna and Chisana rivers, to the east. It is about 20 miles long from the top of Mount Wrangell to the terminus, and has an area of approximately 140 square miles.

Small glaciers in the Copper drainage.—East of the main ice-body there are three small glaciers which lie high up the rock-wall and fail to send their ice-tongues down to join the main lobe. On the west, West Glacier moves from Mount Sanford down to the main valley, which it reaches three miles below the end of the Copper Glacier. Drop Glacier, still farther to the northwest, is the last ice-tongue of importance within the boundaries of the region under discussion.

Glacio-fluvial deposits.—Below the edge of the mountains the great Copper River basin extends to the north and west. The basin is covered with extensive gravel deposits which contain a great variety of beds ranging from coarse gravels and unassorted glacial till to finely assorted clays and silts. The extension of these beds to the west and south has been discussed by Mendenhall.[1] Toward

[1] *Op. cit.*, pp. 62–72.

their upper end they appear as a broad plain into which the rivers have cut considerable valleys.

Extent of earlier glaciers.—In the Copper River Valley, as in all the valleys of these mountains, the ice has formerly been much more extensive than at present. The mountain just below the glacier was once surrounded, and perhaps entirely covered by the ice. Mendenhall advanced the opinion that the entire Copper River basin was probably at one time occupied by ice.

NABESNA VALLEY

Nabesna Glacier.—The Nabesna Glacier is the great body of ice which occupies the head of the valley of the same name. It receives the ice from a great portion of the north slopes of the Wrangell Mountains, its feeding-ground extending from Mount Wrangell in an east-southeast direction to Mount Regal, a distance of 43 miles. The outlines of the glacier form a complicated dendritic pattern, as about 40 cirques contribute their ice to it. At a point 20 miles northeast of Mount Blackburn the ice is confined within a single valley and forms a lobe a little more than two miles wide. Below this point the glacier is of nearly uniform width, and receives but a single important tributary. It moves from this point northeast and then north to its terminus, a distance of 20 miles. The total length of the glacier, from Mount Wrangell to its lower end is about 55 miles, and its area approximately 400 square miles.

As viewed from the mountain-side, below Nikonda Creek (Fig. 2), the main lobe of the glacier shows a fairly smooth surface and a uniform slope as far as the eye can see. There are no cascades or steep pitches on the surface, although the great branch which comes in from the direction of Mount Regal descends steeply into the main valley. The surface slope of the main lobe is about 50 feet per mile.

Moraines.—A prominent medial moraine follows the center of the glacier for many miles above its lower end. It is flanked closely on either side for a part of its length by narrower parallel moraines. The débris showing on the surface becomes more prominent to the northward, and near the terminus the band-like ridges become so frequent that at its north edge the ice is entirely covered by rock débris, and grades imperceptibly into the terminal moraine.

About one mile above Nikonda Creek a rock island or nunatak stands up through the ice. Its surface is covered with loose material, but is bare of vegetation.

The terminal moraine of this glacier covers the valley floor for about two miles below the ice-edge, except for narrow valleys on the east and west through which the waters of the melting glacier escape to the north. The moraine surface is of very irregular topography,

FIG. 2.—The Nabesna Glacier.

and consists of a succession of hummocks and kettles, many of which contain lakelets. No well-established drainage lines were observed.

The extent of the terminal moraine shows that the glacier is at present retreating. It has been deposited so recently that over most of it no vegetation has as yet obtained a foothold. Along the northern edge there is a low growth of bushes, but no trees of size.

Small glaciers in the Nabesna drainage.—There are a number of small glaciers to be found at the heads of tributaries of the Nabesna, which themselves do not connect with the main glacier, or extend

down to the trunk valley. Of those on the east five drain into Nikonda Creek, nine into Bond Creek, three into Camp Creek (Fig. 3), at least one into Cooper Creek, and three into Stone Creek. From the west, about ten glaciers drain into Jacksina Creek and one into Platinum Creek. Almost all these are cliff glaciers of small area, and are but the remnants of larger bodies of ice which formerly occupied the valleys.

Glacio-fluvial deposits.—The Nabesna Valley, from the terminal moraines to the north base of the Nutzotin Mountains, is floored by

FIG. 3.—Glacier at the head of Notch Creek, and small cliff glaciers on the walls above.

gravel beds. The bars are from one to three miles wide, and the river anastamoses over much of this flat in periods of high water. Although the current is swift, the stream is heavily loaded, and the flat is constantly being built up by the outwash from the glacier.

The stream fluctuates daily in volume in the summer season. It is a well-recognized fact by travelers in this region that streams which are not fordable in the afternoons of warm days can be easily crossed on cold days, or in the early morning before the melting ice has swelled the current. In times of high water the main channels may locally deepen their beds. Large bowlders are moved, and can often be heard bumping along the bottoms of the streams. At the same time, the heavily burdened waters may be depositing rapidly in the shallower and more sluggish channels. In the night time,

and on cold days, deposition is general throughout all the stream-courses.

The character of the valley gravels changes notably as one proceeds down stream. Near the glacier the gravels are generally coarse. Farther down they become progressively finer and finer, and bars of small gravel and sand take the place of the cobbles so abundant above.

All of the larger tributaries of the Nabesna River, including Nikonda, Bond, Cooper, and Stone creeks from the east, and Monte Cristo, Jacksina, Jack, and Platinum creeks from the west, have gravel bars similar in origin to those in the main Nabesna Valley, but smaller in size.

Terraces.—The conditions for the deposition of the gravel beds in the Nabesna Valley have not been uniform since the withdrawal of the greater glacier, and it is not to be expected that they would have been. The retreat of the ice probably consisted of many withdrawals interrupted by halts, or even by slight readvances, and from time to time the quantity of water, as well as the abundance and variety of the materials to be transported would have varied. At times of ice-advance the streams were supplied with an excessive amount of detritus, and would therefore have built up their beds with great rapidity. Later, with a comparative scarceness of gravels to be carried, the streams would have been able to entrench themselves in the gravel bars already formed. That some such conditions actually did exist is shown by the terraces of stream-laid gravels which are now to be seen at various places along the Nabesna Valley. These terraces have their best development between Bond Creek and California Creek. At their upstream end they reach an elevation of about 200 feet above the river, but slope gradually downward to the north, and near Bond Creek merge with the gravel bars which the river is now building.

Just south of California Creek, the plain-like surface of the terraces is broken by a number of low, irregular hillocks, composed of glacial till. These indicate that the terrace gravels were here laid down around and on top of a terminal moraine during the retreat of the glacier. The stream has now cut its channel 200 feet into these gravel beds.

For some distance above Camp Creek, and between Copper and Stone creeks, there are gravel terraces which stand 30 to 50 feet above the stream.

Extent of earlier glaciers.—As shown in Fig. 1, the Nabesna Glacier was formerly of much greater size than it is at present. The glaciers from the Wrangell Mountains, moving northward, were unable to override the opposing Nutzotin Mountains, but sent their ice across this range through the two great troughs through which the Nabesna and Chisana rivers now flow. In the Nabesna Valley the ice extended to the north base of the Nutzotin Mountains, and there spread out into a broad, spatulate lobe. The outlines of this lobe have not been traced, but there is reason to believe that its northern edge was 40 or 50 miles below the existing ice-edge. The ice filled the valley to a depth of 2,000 to 3,000 feet, and its erosive power was enormous. It truncated the lower ends of the rock spurs on either side of the valley and developed the broad U-shaped trough through which the river now flows. There is a notable absence of craggy outcrops and of ridge-like spurs along the valley-sides.

At the time of the maximum ice-advance each tributary valley in the Wrangell and Nutzotin mountains sent down a glacier to join the main lobe so that only the highest peaks and crests of the mountains projected above the ice. With a change in climatic conditions came a gradual contraction of the glaciated area. The ice in the large trunk valley slowly melted back and left separate the small glaciers which occupied the side gulches. These in turn retreated toward their heads, and although many of them have now disappeared entirely, their former presence is shown by the U shape of the stream-troughs, and by the moraines which the ice left.

CHISANA VALLEY

Chisana Glacier.—The Chisana Glacier, locally called the Shushana, lies on the northeast slope of the Wrangell Mountains, between the Nabesna and White valleys. Its heads reach westward to the Nabesna divide, and in many of the cirques the ice is continuous across the divide with the easternmost heads of the Nabesna. To the south the ice is continuous over the divide with the Rohn and Nizina glaciers on the south slope of the mountains (Fig. 4). There

are but 14 tributary cirques, as compared with 40 to the Nabesna Glacier, and the total area of ice is about 135 square miles. Its length, from the terminus to the Chisana-Rohn divide, is 30 miles.

FIG. 4.—The summit of the Chisana-Rohn divide. Photograph by Rohn, 1899.

A fine view of the glacier can be obtained from Euchre Mountain, at its lower end. The glacier, which for about twelve miles above Euchre Mountain consists of a single lobe, swings in a broad curve from a north to an eastern direction. Its surface, so far as could be

FIG. 5.—Lower end of the Chisana Glacier. Photograph by Rohn, 1899.

seen, was free from sharp breaks in gradient and from prominent crevasses (Fig. 5).

Moraines.—A prominent medial moraine belt, lying somewhat west of the center of the glacier, appears on the surface far above the great bend of the ice. At the bend it has a curious zig-zag shape,

and extends to the ice-edge above Euchre Mountain. It is the only continuous belt of moraine to be seen from this mountain.

There is an almost complete absence of distinct terminal moraine deposits, and it is concluded that the glacier is retreating. If this is the case, however, the ice-movement must be very slow, for a comparison of the photographs taken by Rohn[1] in 1899 with those taken by the writer nine years later show surprisingly little change in the aspect of the glacier. The moraines appear the same, and there are only slight changes in the courses of the streams below the ice-edge. At one place a slight recession has taken place in the edge of the glacier.

Small glaciers in the Chisana drainage basin.—There are a number of small glaciers which drain into the Chisana Valley. On the east several little ice-lobes project down from the ice-field which caps the mountains southeast of Euchre Mountain. These form the heads of Bow and Gehoenda creeks. On the west, four small glaciers drain into Cross Creek, two from the Wrangell Mountains (Fig. 1), and five from the Nutzotin Mountains into Notch Creek. Mount Allen supports two little ice-tongues which drain into the Chisana below the mouth of Cross Creek.

Glacio-fluvial deposits.—The valley below Euchre Mountain contains broad gravel bars built up by the streams from the glacier. The stream-laid deposits differ notably, however, from those found immediately below the Nabesna Glacier. Here coarse gravel is the exception, and as far north as the mouths of Cross (Copper) and Chavolda creeks, the bars are largely composed of fine gravels and sands. The valley is wide and the stream breaks up into a multitude of channels. On the afternoons of warm days, these channels were observed to overflow and join until much of the wide flat was covered by a thin sheet of water.

Below the mouth of Cross Creek, the gravels become much coarser, as this creek discharges coarse gravels. The valley through the Nutzotin Mountains is a narrow U-shaped gorge, and the waters flow in a few large channels. Through the gorge there is shown the usual succession of coarse gravels above, becoming progressively finer down stream.

[1] Oscar Rohn, *21st Ann. Rept.*, U. S. Geological Survey, Part II, Pl. LV.

All of the larger tributaries of the Chisana River, including Bow, Gehoenda, Chathenda, and Chavolda creeks from the east and Cross Creek from the west, have valleys floored with gravels, and most of these streams have developed fans where their gravel bars coalesce with those of the main valley.

Terraces.—Conspicuous terrace deposits occur at several points along the valleys of the Chisana and its tributaries. East of Euchre Mountain, and including the lower portions of Bow, Gehoenda, and Chathenda creek valleys, there is a broad area of gravel deposits into which these streams have entrenched themselves. The area now covered by these gravels was formerly occupied by the Chisana Glacier. As the glacier decreased in size the ice-edge gradually shrank back toward the west and exposed this region, while it was still of sufficient thickness in the main Chisana Valley to form an obstruction to the streams from the east. Under these conditions the creeks rapidly built up their valleys with alluvial material. It is even possible that temporary lakes were formed behind the ice-dam. An exposure along Gehoenda Creek for several miles above its mouth shows fine, stratified gravels and silts, interbedded with coarser materials. The rather perfect stratification of the finer materials suggests a lacustrine origin for these beds.

On Notch Creek there are terrace gravels on both sides of the stream. They occur intermittently from the base of the mountains near the head of the creek to its mouth, and in places the stream-cut bluff shows a section of 150 feet of the coarse, rudely stratified gravels with interbedded lenses of sand. They are evidently stream-laid and may have been deposited synchronously with the terraces in the Nabesna Valley described above.

About ten miles below the mouth of Chavolda Creek, on the northwest side of the Chisana River, there is a good exposure of terrace gravels. In the bank about 60 feet high the lower 40 feet are exposed. The section (Fig. 6) shows 15 feet of coarse gravel at the base, with occasional bowlders 18 inches in diameter. Above this is 25 feet of fine, well-stratified gravel with pebbles five inches or less in diameter. The terraces were probably built contemporaneously with those in Notch Creek.

Extent of earlier glaciers.—As is the case in other valleys of this

region, the Chisana trough has very evidently been occupied at no very remote period by a glacier of much greater extent than the present one. It pushed from the Wrangell Mountains northeast through the Nutzotin Mountains to their north base, and was very deep throughout the valley. On Euchre Mountain there are moraines and erratic bowlders up to the 6,600-foot level, or 2,500 feet above the terminus of the present glacier, and in the low col west of this mountain there must have been at least 1,200 feet of ice which moved northward. Euchre Mountain at that time was an island standing about 1,000 feet above the surface of the surrounding glacier. East and northeast of Euchre Mountain the ice was not confined by steep valley-walls, and doubtless spread out into a wide lobe at this place. Below Chavolda and Cross creeks it was again compressed to a narrow tongue in the canyon-like valley through the Nutzotin Mountains, and probably again deployed on the plain to the north of this range.

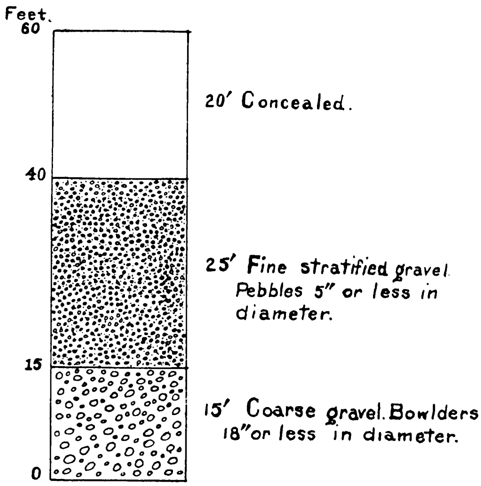

FIG. 6.—Section of gravel terrace on the Chisana River, 10 miles below the mouth of Chavolda Creek.

At the climax of this glacial period, each tributary valley of the Chisana, both in the Wrangell and Nutzotin mountains, was occupied by a glacier which joined the body of ice in the main valley. It is probable that the whole mountainous area had much the same appearance at that time as that shown by the higher parts of the Wrangell Mountains now (see Fig. 4).

Since the retreat of the ice to its present position, the greater number of tributary valleys have been deglaciated; and only the higher and more favorably situated summits have perennial ice upon their flanks.

In the canyon of the Chisana, between the mouth of Chavolda Creek and the north base of the mountains, the rock valley walls show in many places one or more smooth, rounded benches, due to glacial erosion. The benches are inconspicuous when near at hand, but are plainly discernible from a distance. They can rarely be followed for more than a mile or so, and it was impossible, in the short time available, to correlate the benches in different parts of the canyon.

WHITE VALLEY

Russell Glacier.—The head of the White River is occupied by a body of ice which was first crossed in 1891, by C. W. Hayes, and was named Russell Glacier[1] by him. The pass over this glacier he named Skolai Pass, and from this fact the name Skolai Glacier is commonly used in the region. The feeding-ground from which this ice-field moved is located in the high mountains east and southeast of Skolai Pass, and as these mountains have never been accurately mapped, no data is available for determining the area and length of the glacier.

As stated above, all the valleys which supply ice to the main glacier head to the east and south. The northernmost of these, at the head of Moraine Creek, joins the main lobe near its terminus. The tributary valley divides, a short distance above its mouth, into two cirques which head in the snow-capped mountains to the east. South of Moraine Creek there are four important tributary glaciers, all of which have their sources in the high, snow-capped, unexplored mountains (Fig. 7).

The main lobe of ice in the head of the White Valley is between 6 and 7 miles long, and about $2\frac{1}{2}$ miles wide, and most of the ice moves in a northeast direction. A small crescentic lobe, however, moves westward into the head of Skolai Creek.

The surface of Russell Glacier is for the most part much crevassed and difficult to cross. The lower two or three miles of ice are moraine-covered, and have been melted into rugged surface shapes in which the ice can be seen only where the slopes are too steep to hold the moraine material. Numerous lakelets were seen to occupy basins in the ice (Fig. 8). Above the moraine-covered portion of the glacier

[1] *Nat. Geog. Mag.*, Vol. IV, 1892, p. 152.

there is a belt, near the west edge, in which the surface is free from

FIG. 7.—View showing surface character of the upper portion of Russell Glacier.

débris and level enough to make travel easy. Here there are few crevasses for a distance of perhaps three miles. As the lobe which

FIG. 8.—A lake in the moraine-covered ice of Russell Glacier.

moves into the valley of Skolai Creek is approached, the ice-surface again becomes broken and irregular, with rugged, moraine-covered

areas and great systems of cracks at right angles to the Skolai Creek Valley (Fig. 9). There is little terminal moraine bordering this lobe, and Skolai Creek has a flat bar composed for the most part of silty quick-sands.

Moraines.—A number of belts of medial moraine lie upon the surface of this glacier. The most important one extends continuously down the center of the main ice-lobe. Other less conspicuous lines occur below the junction-points of the various heads.

The terminal moraine forms a great lobe at the head of White River. It was impossible to determine the line where the glacier ice ends and the terminal moraine begins, as the two blend imperceptibly. A considerable area of the ice is moraine-covered, and there is doubtless much ice inclosed in the moraine deposits. The moraine is a confused jumble of fine material and rock fragments of all sizes and shapes. Drainage lines have been developed only along its edges.

Russell Glacier seems to be retreating. The terminal moraine is new and barren of vegetation, and the ice above it is much decayed. The comparatively recent age of the moraine is also attested by a large admixture of the volcanic ash which is of widespread occurrence in this region, and which lies as a white covering on the lower spurs of the ridges north of Mount Natazhat.

Small glaciers in the White River basin.—In some of the tributary valleys to the west and south of the White River there are small glaciers, the remnants of ice-tongues which formerly reached down to the main valley. In Middle Fork and Lime creeks to the west, the valley-heads contain glaciers, and smaller ice-fields lie on favorable places along their walls. Wiley Creek, to the east of the great terminal moraine, has an ice-field at its head. All the small streams which join the White River between the great bend and Holmes Creek, head in lobes of the ice-cap which covers the range. Holmes Creek has a deep valley which extends for some distance back into the mountains, and a glacier occupies this canyon to its mouth. Mount Natazhat and the great ridge extending west from it, form a series of magnificent cirques, with ice-tongues which extend to the foot of the mountains (Fig. 10).

Glacio-fluvial deposits.—The gravel deposits now being laid down

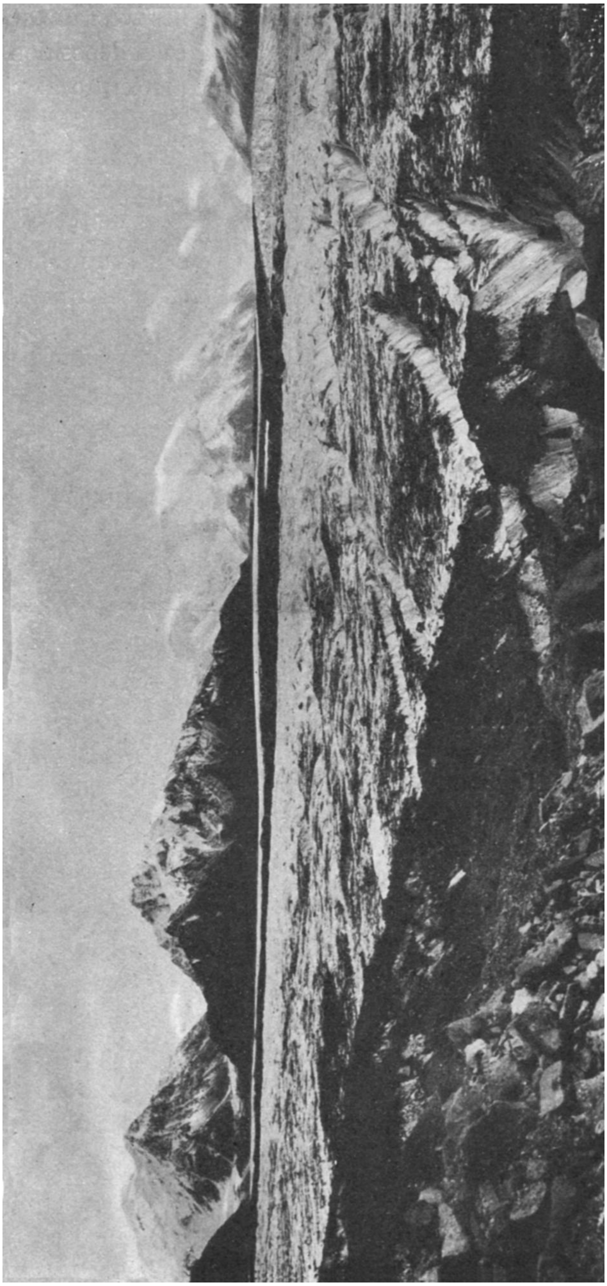

FIG. 9.—View toward the head of Russell Glacier. A medial moraine appears in the immediate foreground, and another in the middle distance.

in that part of the White River Valley which lies west of the international boundary, are very extensive. The area of deposition varies in width from about two miles, just below the glacier, to about nine miles, south of Mount Natazhat. For the first ten miles below the glacier the valley is flat from side to side and is for the most part bare of vegetation. East of Ping Pong Mountain, the White River itself occupies only a narrow valley close to the base of a rock ridge. The remainder of the broad valley to the south slopes upward toward the mountains, and consists of a compound alluvial fan built up by

FIG. 10.—Mount Natazhat, and the great cirques on its flanks. Each of these cirques is occupied by a glacier. Photograph by F. H. Moffit.

the tributaries from the south. This fan is heavily timbered except for narrow belts along the streams. The present course of the White River has been determined by this alluvial fan which has crowded the river north against the base of Ping Pong Mountain.

Fig. 11 is a diagrammatic cross-section of the White Valley, five miles west of the boundary. If we can assume that the wide valley north of Mount Natazhat was eroded by the great glacier to an average depth equal to the present level of the White River (*a*), then the valley filling of alluvial gravel must be more than 400 feet thick in the center of the old valley (*b*). Since the White River was nowhere observed to have cut its valley down to bedrock, and since the bedrock level at (*b*) is probably lower than at (*a*), the thickness of the gravels in the deepest portions of the old valley may greatly exceed 400 feet.

Aside from the fan-building streams from the south, the valleys of North Fork, Lime Creek, Middle Fork, and Wiley Creek all have gravel bars extending upstream for some distance above their junctions with the White River gravels.

Terraces.—In this valley remnants of high terraces were noted only on the north side of the river. For about two miles below the mouth of the Lime Creek Canyon, there is a bench of coarse gravels from 30 to 50 feet high. Farther east, along the south base of the Ping Pong Mountain ridge, the river bluff shows a 50-foot cut. Of this section (Fig. 12), the lower 35 feet are composed of coarse, rudely stratified

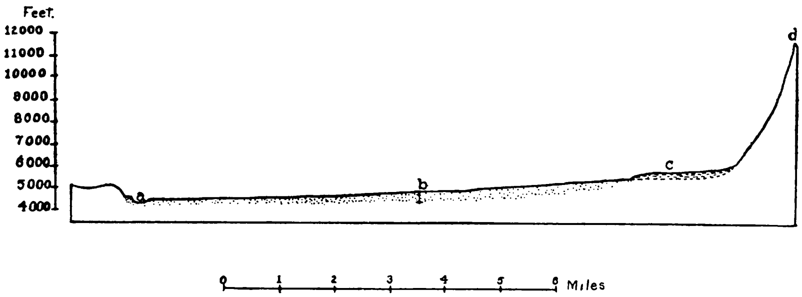

FIG. 11.—A north-south section across the White River Valley, about 5½ miles west of the international boundary. *a*, White River; *b*, alluvial fan; *c*, small glacier; *d*, peak two miles west of Mount Natazhat.

gravels. Above this are 15 feet of blue glacial till. Locally the gravel beds immediately below the till are much distorted and crumpled, showing that after the gravels were deposited, the glacier advanced over them, disturbing their bedding and depositing a sheet of till. There may be gravels of the same age south of the White River, but the present tributaries from the mountains to the south are so actively engaged in building alluvial fans that any remnants of higher terrace gravels which might have existed on that side of the river have been cut away, or covered up by more recent deposits.

Extent of earlier glacier.—At the time of the great ice-advance, a glacier, of which Russell Glacier is the surviving remnant, moved eastward along the White Valley and extended well across the international boundary. At the boundary it had a width of more than 10 miles, and its surface stood more than 1,600 feet above the present level of the White River at this place, for there are evidences of glacia-

tion at the top of a 1,600-foot hill just east of the boundary. The glacier also covered the ridge of which Ping Pong Mountain is the west end. Unlike the ice-fields which occupied the Nabesna and Chisana valleys, this one was not fed by tributaries from both sides of its valley, but only from the valleys of the high mountains to the south and west.

The severity of the glacial erosion upon the valley walls is well shown by the abrupt triangular faces of the spurs opposite the mouths of North Fork and Solo creeks.

Solo Creek gravels.—North and west of Solo Creek there is a broad, flat area covered with outwash gravels, which were laid down under much the same conditions as were those east of the Chisana Glacier. Here the receding ice in the White River Valley left bare a broad area which normally drained into the White River. The drainage was here impeded by the valley glacier, which must have occupied the valley long after the higher area to the north was deglaciated. During this period of obstructed drainage extensive gravel beds were laid down, which abutted against the ice to the south, and spread northward and filled the old drainage channels. The filling went on to such an extent that some of the streams found a lower outlet to the northeast, and still flow in that direction. Solo Creek has now cut a considerable gorge through the gravels and into the underlying rock, and is gradually recapturing for the head of the White River the drainage lost during early glacial times.

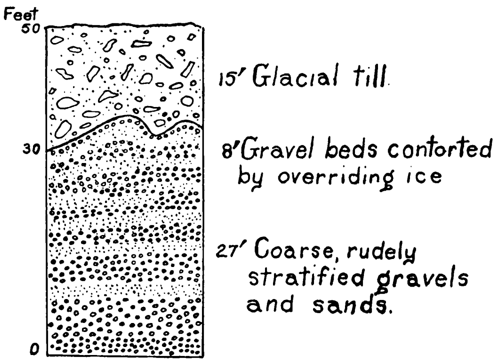

Fig. 12.—Section of terrace on White River, showing glacial till above, and gravels below. The upper portion of the gravel beds has been distorted by the over-riding ice.

Ptarmigan Lake gravels.—Between North Fork and Ping Pong Mountain, a broad flat has a gravel covering due to the same causes as those which brought about the deposition of the Solo Creek gravels.

Ptarmigan Lake would normally drain into the White River to the south, but its waters found an outlet by way of Beaver Creek at the time the glacial ice in the White River Valley formed a barrier to drainage in that direction. The development of its gulch by Cache Creek may some day result in the recapture of this drainage, as the gulch is now being rapidly deepened headward.

GLACIERS IN SKOLAI CREEK DRAINAGE

Skolai Creek is the stream which flows eastward from a lobe of Russell Glacier, and after traversing a narrow, deep valley for about 17 miles, is impounded to form a lake at the edge of the Nizina

FIG. 13.—Terminus of Frederika Glacier. This glacier terminated, in 1891, in an ice-cliff 250 feet high. Photograph by F. H. Moffit.

Glacier, and has its outlet beneath this ice-dam. From the north a single ice-lobe, Frederika Glacier, drains into Skolai Creek. C. W. Hayes, who saw this glacier in 1891, says of it,

> The glacier terminates in a nearly vertical ice cliff stretching across the lateral valley a mile in length, and about 250 feet high. Its surface is free from moraine, but is extremely rough and broken, wholly unlike the surface of stagnant ice at the end of a retreating glacier.[1]

He also mentions this glacier as being the only one seen that summer which appeared to be actively advancing. As seen by the writer, the

[1] *Nat. Geog. Mag.*, Vol. IV, 1892, p. 133.

glacier now terminates about one mile north of Skolai Creek. Its surface is remarkably smooth and slopes down evenly to a thin edge in front (Fig. 13). It was found to be easier to take a pack train across this low ice-tongue than to ford the torrential stream below.

From the south, a number of glaciers drain into this valley. About three miles below Russell Glacier a moraine-covered ice-lobe pushes down to the valley and dams the stream so that a considerable lake is

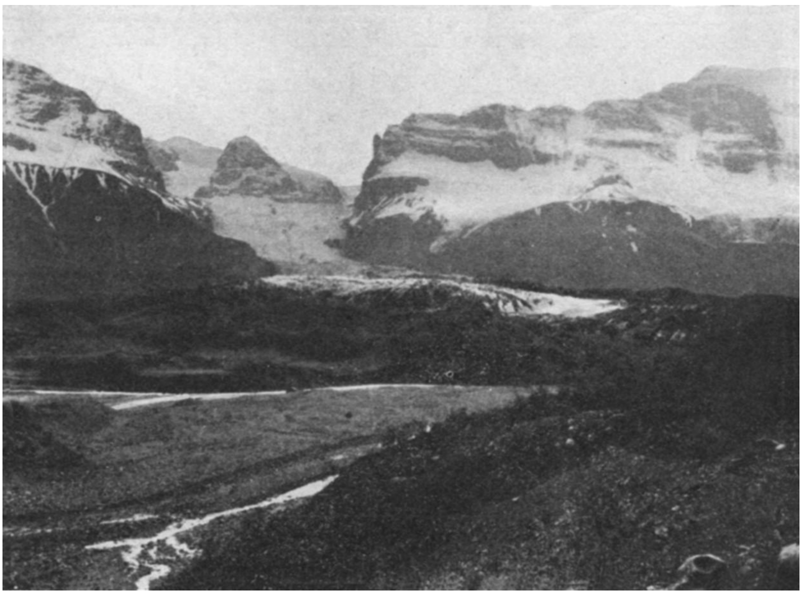

FIG. 14.—An advancing glacier in Skolai Creek Valley, opposite Frederika Glacier.

formed. Opposite the mouth of Frederika Creek, a beautiful cascade glacier tumbles out from between castellated peaks and pushes northward to Skolai Creek (Fig. 14). It is evidently an advancing glacier now, and was the only one seen during the season which seemed to be advancing. The writer is unable to account for the singular change in conditions which has caused Frederika Glacier, which 17 years ago was advancing, to retreat, and at the same time has brought about the advance of a glacier just to the south, which in 1891 was retreating.

Below Frederika Creek there are several small cliff glaciers on the south valley-wall. At their heads the rock rises almost perpendicularly for a thousand feet or more. On a warm afternoon, great blocks of ice from above could be seen to break off and fall down this cliff with a great noise. The ice was broken to fine fragments before it reached a lodgment below.